Engineering Standard

SAES-J-604 30 July, 2003

Protective and Condition Monitoring Equipment for Rotating Machinery

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Revised paragraphs are indicated in the right margin

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1 Scope

1.1 This standard defines the minimum mandatory requirements governing the design and installation of protective and condition monitoring equipment for rotating machinery.

1.2 This standard does not apply to electric motor and generator stator temperature monitoring equipment.

1.3 This entire standard may be attached to and made a part of purchase orders.

2 Conflicts and Deviations

2.1 Any conflicts between this standard and other applicable Saudi Aramco Engineering Standards (SAESs), Materials System Specifications (SAMSSs), Standard Drawings (SASDs), or industry standards, codes, and forms shall be resolved in writing by the Company or Buyer Representative through the Manager, Process and Control Systems Department Saudi Aramco, Dhahran.

2.2 Direct all requests to deviate from this standard in writing to the Company or Buyer Representative, who shall follow internal company procedure SAEP-302 and forward such requests to the Manager, Process and Control Systems Department of Saudi Aramco, Dhahran.

3 References

The selection of material and equipment, and the design, construction, maintenance, and repair of equipment and facilities covered by this standard shall comply with the latest edition of the references listed below, to the extent specified herein.

Saudi Aramco References

Saudi Aramco Engineering Procedure

SAEP-302	*Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement*

Saudi Aramco Materials System Specifications

13-SAMSS-001	*Special Purpose Gear Units*
13-SAMSS-003	*General Purpose Gear Units*
17-SAMSS-502	*Form-Wound Induction Motors 250 HP and Above*
17-SAMSS-520	*Form-Wound Brushless Synchronous Motors*

27-SAMSS-003	*Manufacture of Non-Industrial Cooling Towers*
30-SAMSS-001	*Diesel Engines*
31-SAMSS-001	*Centrifugal Compressors*
31-SAMSS-002	*Packaged Reciprocating Plant & Instrument Air Compressors*
31-SAMSS-003	*Reciprocating Compressors for Process Air or Gas Service*
31-SAMSS-004	*Centrifugal Pumps*
31-SAMSS-005	*Centrifugal Fluorocarbon Refrigeration Units for Industrial/Process Service*
31-SAMSS-006	*Packaged, Integrally Geared Centrifugal Air Compressors*
31-SAMSS-012	*Shaft Sealing Systems for Centrifugal & Rotary Pumps*
32-SAMSS-009	*General Purpose Steam Turbines*
32-SAMSS-010	*Special Purpose Steam Turbines*
32-SAMSS-011	*Manufacture of Air-Cooled Heat Exchangers*
32-SAMSS-013	*Lubrication, Shaft-Sealing and Control Oil Systems*
34-SAMSS-625	*Machinery Protection Systems*

Saudi Aramco Engineering Standards

SAES-J-601	*Emergency Shutdown and Isolation Systems*
SAES-K-502	*Combustion Gas Turbines*

4 General Requirements

4.1 Definitions

4.1.1 Vibration, Axial Position and Bearing Temperature Monitoring System - The monitoring system consists of probes, accelerometers, and temperature sensors; signal conditioning devices (if required); interconnecting cables; racks; power supplies; monitors; and communication devices.

Commentary Note:

For simplicity, the remainder of the document will define the "Vibration, Axial Position and Bearing Temperature Monitoring System" as the "Vibration Monitoring System".

4.1.2 Rotating Machinery Protection System (RMPS) - The logic system that receives the shutdown inputs, processes the machinery protection logic and automatically sends shutdown commands to the rotating equipment train. The RMPS logic solver shall be one of the following; Distributed Control System (DCS) or auxiliary control system (VMS), Simplex Programmable Logic controller (PLC), or PLC based ESD system. For process critical rotating machinery, the RMPS logic solver shall meet the requirements for Emergency Shutdown Systems. Critical rotating machinery is defined in SAES-J-601.

4.1.3 Condition Monitoring System - A computer based data collection system that communicates directly with the vibration monitoring system and will also accept process data via the VMS or a communication link to the DCS. The computer(s) shall collect, store, process, display and print the machinery data in a variety of formats.

Commentary Note:

This data will typically be used for historical trending, machinery diagnostics, and predictive maintenance purposes, not for shutdown protection.

4.2 Rotating Machinery to be Protected

Commentary Note:

The protective instrumentation required for each type of rotating machinery is located in the applicable Saudi Aramco Materials System Specifications (SAMSSs) or Saudi Aramco Engineering Standards (SAESs).

Rotating machinery to be protected shall include, but not be limited to:

4.2.1 Gear Units; (13-SAMSS-001 and 13-SAMSS-003)

4.2.2 Form-Wound Induction Motors 250 HP and Above; (17-SAMSS-502)

4.2.3 Form-Wound Brushless Synchronous Motors; (17-SAMSS-520)

4.2.4 Diesel Engines; (30-SAMSS-001)

4.2.5 Centrifugal and Reciprocating Compressors; (31-SAMSS-001, 31-SAMSS-002, 31-SAMSS-003, 31-SAMSS-005 and 31-SAMSS-006)

4.2.6 Centrifugal Pumps; (31-SAMSS-004)

4.2.7 Steam and Combustion Gas Turbines; (32-SAMSS-009, 32-SAMSS-010 and SAES-K-502)

4.2.8 Hydraulic Couplings (apply the requirements in 13-SAMSS-001)

4.2.9 Combustion Air Fans with a discharge pressure greater than 34 kPa (5 psi) above atmospheric pressure; (apply the requirements in 31-SAMSS-001)

4.2.10 Combustion Air Fans with a discharge pressure less than 34 kPa (5 psi) above atmospheric pressure; per Manufacturer's recommendation with Proponent approval.

4.2.11 Air-cooled heat exchangers (apply the requirements in 32-SAMSS-011).

4.2.12 Non-Industrial Cooling Towers (apply the requirements in 27-SAMSS-003)

4.3 Lubrication, Shaft-sealing and Control Oil Systems

Lubrication, shaft-sealing and control oil instrumentation shall comply with 31-SAMSS-012 and 32-SAMSS-013.

4.4 Shutdown Signals

All shutdown signals for the rotating equipment train shall be wired directly to the RMPS logic solver. Shutdown signals may originate from three sources:

1) The vibration monitoring system (based on bearing temperature, vibration, and axial position sensors),

2) Lubrication, shaft-sealing and control oil instrumentation (if applicable); and

3) Process shutdown devices.

5 Vibration Monitoring System (VMS)

5.1 Hardware (sensors and instruments) and Setpoint Requirements

5.1.1 The vibration monitoring system shall comply with 34-SAMSS-625.

5.1.2 All vibration, axial position and bearing temperature monitoring instrumentation installed for a single machinery train shall be from the same equipment manufacturer.

Exception:

Accepted practice and the intent of 34-SAMSS-625 (and API STD 670) is to bring bearing temperature sensors into the VMS. However, bearing temperature monitoring can be implemented in any RMPS logic solver upon approval by the Proponent organization. In either case, the CMS always looks at the temperatures and having them in the VMS makes this correlation cleaner.

Commentary Note:

Field sensors are not required to be from the same equipment manufacturer as the VMS.

5.1.3 The radial shaft vibration, bearing housing vibration, axial position, and bearing temperature limits for alarm (alert) and shutdown (danger) setpoints shall be in accordance with the rotating machinery manufacturer, or the existing field data, or from the Proponent organization. All temperature inputs shall provide burnout detection. The direction of the readout or output signal upon temperature sensor burnout shall be selectable (either upscale or downscale).

5.2 Communication to Distributed Control System

5.2.1 The vibration monitoring equipment shall be capable of providing communications to a distributed control system (DCS) via a serial link (RS-232/422/485) or Ethernet. Modicon Modbus communication protocol shall be used.

Exception:

If the VMS vendor has a tightly integrated high speed communications link with a particular DCS vendor, then this communication link shall be used in lieu of the serial/Ethernet Modbus data link.

5.2.2 The internal date and time clock of the vibration monitoring equipment shall be capable of synchronizing with an external clock signal, e.g., a DCS clock.

5.2.3 The following information shall be communicated and displayed via the DCS MMI.

a) Channel value for each variable.
b) Armed/disarmed shutdown (bypass) status for all channels.
c) Transducer OK (Status) limit for each channel.
d) Hardware and software diagnostics.
e) Communication link status.

f) Gap Alarm for each channel, when applicable.

5.2.4 The following items shall also be made available to the DCS through the serial communication link: (ref. 34-SAMSS-625).

a) Channel status of alarm or no alarm.

b) Alarm storage for storing the time, date, and value for a minimum of 64 alarms.

c) Measured value as scaled engineering unit values or a percent of alarm (alert) and shutdown (danger) values to 1% resolution.

d) Alarm and Shutdown setpoints.

e) Time stamp and date for all transmitted data.

f) System entry log to include date, time, individual access code, and record of changes.

Commentary Note:

The Proponent organization shall determine which additional item listed in Section 5.2.4, if any, will be communicated and displayed in the DCS MMI.

5.3 Alarm (alert) and Shutdown (danger) Outputs

5.3.1 For fully or partially attended facilities both the alarm and shutdown outputs shall be annunciated on a visual alarm display, and with an audible alert signal. For unmanned facilities only the shutdown output shall be visually annunciated.

Commentary Note:

The audible and visual annunciation shall be in a discrete, multi-point alarm annunciator or to an alarm/annunciator display configured within a DCS system.

5.3.2 The shutdown output from the VMS danger relay (based on vibration, axial position, or bearing temperature sensors) shall be hardwired to the RMPS logic solver. The shutdown signals for each equipment train can be commoned.

5.3.3 Redundant relay cards shall be used for rotating equipment categorized as 'process critical', i.e., one shutdown contact from each relay card shall be routed to the logic solver. Dual voting logic (two-out-of-two) shall be used to trip the machine.

Commentary Note:

Process Critical equipment is defined in Section-4 of SAES-J-601.

5.3.4 The shutdown contacts shall be wired fail-safe. The fail-safe state shall be the deenergized state. The alarm and shutdown contacts shall be closed during normal operation and shall open when the alarm or shutdown condition is reached.

5.4 Hot Insertion or Removal of Modules

Any main module, installed in the front of the rack, shall be capable of being removed and replaced while the system is under power without affecting the operation of other unrelated modules.

5.5 Module Segregation

5.5.1 It is permissible to install the monitors for more than one rotating equipment train in one (1) rack, if redundant power supplies are used.

5.5.2 Each rotating equipment train (including duty/standby equipment) shall be terminated on separate monitor I/O modules.

5.5.3 If the VMS equipment manufacturer uses a programmable relay module which can use alarm inputs (alert and danger signals) from any monitor channel or any combination of monitor channels in a rack, then each equipment train shall have a separate relay module. For process critical equipment redundant relay cards shall be used, reference section 5.3.3.

5.6 Power Supply

5.6.1 Vibration monitoring systems shall be powered from branch circuits of the plant UPS.

5.6.2 For all critical machinery, dual power supplies with separate UPS branch circuit feeds shall be used. If the VMS contains more than one rack, then all "A" power supplies shall be on one branch circuit, and all "B" power supplies shall be on a separate branch circuit.

5.6.3 Each rack in the VMS shall be capable of accepting redundant power supply modules. Each power supply shall have the capacity to power a fully loaded rack. If the rack uses two power supplies, removing or inserting an individual power supply module shall not disrupt the operation of any modules within the rack.

Commentary Note:

Redundant power supplies are required when monitoring multiple machines within a common rack (ref. 5.5.1 above).

5.7 Junction Boxes

5.7.1 Each rotating equipment train shall have a common junction box installed for termination of all the temperature sensor lead wires. All junction boxes shall be located for ease of access and on the same side of the equipment train as the oscillator-demodulator junction boxes. These boxes shall not be mounted on the machine but in a vibration-free environment.

5.7.2 For installation of all oscillator/demodulators and external accelerometer charge amplifier refer to 34-SAMSS-625.

5.8 Condition Monitoring Interface

5.8.1 The VMS shall be capable of interfacing to an external host computer (e.g., personal computer) for on-line "condition monitoring" of steady state and transient machinery operating conditions.

5.8.2 The Condition Monitoring System (CMS) shall be connected to the Plant Network to allow remote access to dynamic data by other Departments.

Commentary Note:

This is a separate and independent connection from the DCS communication port.

6 General Design Criteria Applied to all Rotating Machinery Protection Systems

6.1 Input Bypass Switches

6.1.1 Each RMPS shutdown signal shall be installed with a bypass switch to facilitate maintenance or testing.

6.1.2 Bypass switches in vibration monitoring equipment shall be either hardwired, or software-configured using a restrictive access mechanism such as a key-lock, a password protection scheme, or both.

6.1.3 Activation of a bypass switch, to the bypass position, shall be annunciated on a visual alarm display, and with an audible alert signal.

6.2 Event Logging/Recording

6.2.1 First-out event logging, if required by the Proponent organization, shall be implemented in the plant event logging and archiving system. On critical rotating machinery, the event logging shall be installed per SAES-J-601.

6.2.2 Vibration monitor systems which have the ability to perform on board event logging on a per rack basis are acceptable provided that, the system is designed to accept an external synchronization signal from the plant event logger and can provide the event time discrimination required by the Proponent organization.

7 Condition Monitoring System (CMS)

7.1 Rotating Machinery Requiring Condition Monitoring

The Proponent organization shall determine which rotating machinery, if any, will require "steady state" and/or "transient" condition monitoring equipment.

Commentary Note:

Careful consideration should be given before installing a transient monitoring system due to its relatively high cost and the advanced level of expertise required to interpret the data.

7.2 General Description

7.2.1 The "data acquisition server" is the computer that collects, processes, and stores the data from the vibration monitoring equipment.

7.2.2 The "display client" is the computer which displays the vibration, temperature, and other process data from the data acquisition server.

Commentary Note:

The display client will be capable of requesting data directly from the data acquisition server or remotely either from a distributed network system or via modem remote access. The display client and the data acquisition server could be the same computer (Stand Alone System).

7.2.3 The CMS shall have the capability to be networked (single or multiple client/server) using Windows NT compatible protocols on both Local Area Networks and Wide Area Networks.

7.2.4 When importing or exporting process data, the data acquisition computer(s) shall include the appropriate hardware and software for synchronizating its date and time clock with an external clock signal.

7.2.5 The data acquisition server shall have the capability to interface via serial link using Modbus protocol to one or more plant process computers or controllers for acquiring process data from these devices. Optional protocols shall be addressable via a standardized network dynamic data exchange (NETDDE) interface or application programming interface (API).

Commentary Note:

In areas where there is substantial Electrical Magnetic Interference (EMI) including Radio Frequency Interference (RFI), fiber optics should be considered as the transmission medium of choice.

7.2.6 In a VMS with multiple racks, the data acquisition server shall communicate with the racks using multi-drop architecture. If a failure occurs in any communication device, communication with the remaining racks shall be maintained.

7.2.7 Failure of the condition monitoring equipment including all associated communication devices shall not impact the VMS or the RMPS.

7.2.8 Host computers used for condition monitoring are not required to be powered from the UPS system.

7.3 Stand Alone System

7.3.1 The stand alone system shall be designed for operation using Microsoft Windows NT as the operating system for the data acquisition & display client (with capability for optional display on clients computer(s) running on Windows 98 or NT).

7.3.2 CMS data shall be externally accessible via a modem connection using TCP/IP protocol.

7.3.3 The system shall be network-compatible with existing Novel server systems using either Ethernet or Token-Ring.

7.4 Distributed Network System

7.4.1 The system shall be designed for efficient and compatible networking using Microsoft Windows NT as the data acquisition server and Windows 98 or NT as the display client.

7.4.2 The system shall support multiple data acquisition servers and displays, all connected to a plant network.

7.4.3 Data acquisition servers shall be able to be accessed from any location on the network or from a remote location.

7.4.4 All networked display users must have access to data and configuration information from all data acquisition servers.

7.5 Data Availability

The system shall provide access to the data acquisition server database by third party packages via DDE or application programming interface (API).

7.6 Data Acquisition and Display Client Hardware

7.6.1 The host computer shall be a Pentium or later chip set using an IBM PC workstation or 100% compatible system. The server shall be cluster based and installed in a secure cabinet.

7.6.2 Each data acquisition computer shall be furnished with Windows NT (multitasking) pre-loaded, have the necessary data acquisition card(s) loaded and have a network card and modem.

7.6.3 The data acquisition computer shall have an external data storage device capable of backing up the hard disk.

7.6.4 A manual covering installation and configuration of the system shall be furnished with each computer.

7.7 Condition Monitoring Software

7.7.1 The on-line condition monitoring software shall run on Windows NT.

7.7.2 As a minimum, the configuration software shall incorporate the following features:

a) Configuration must be easily understood via dialog boxes with embedded help screens in the software.

b) Configuration of multiple data acquisition servers and server parameters at any time.

c) Configure points, machine trains, machine train labels, and system preferences.

d) Configuration templates shall be provided along with a feature to apply to multiple points at once.

e) Minimum data variables that can be configured shall include overall direct, four user-programmable filtered ranges, 1X amplitude/phase, 2X amplitude and phase, Gap readings and process variables.

f) Two levels of configurable alarm level setpoints per point.

g) Configure reports for each on-line station consisting of data plots, alarm events list, and system events list. System shall allow reports to be sent to a printer or saved to a file for later review.

h) Configuration of any data acquisition server must be accessible (password protected) from any display station.

i) On line configuration of system parameters shall not alter database structure parameters.

j) Windows style on-line Help and Glossary that is context-sensitive and has flexible search capabilities, hypertext information and graphics. Must be printable by selected topics.

7.7.3 As a minimum, the display software shall incorporate the following features:

a) View all data acquisition servers including data plots, alarm indication lists, individual point and station statuses, and configuration.

b) View point name, machine train name, current reading and point alarm status on one screen.

c) Global alarm indication in all screen views.

d) Ability to display and tile up to four plots on a point with a single command.

e) Minimum plot options should include Current Value, Trend, Configurable Trend (down to 10 minute resolution between data points), Timebase, Orbit/Timebase, Frequency Spectrum, Acceptance Region, Shaft Average Centerline, Spectra vs. Time (Waterfall). Trend plots shall not be compacted.

f) Ability to correlate vibration and process trend data on a single plot.

g) Ability to overlay baseline plots on current spectrum and orbit plots.

h) Ability to overlay baseline plots on current Bode and polar plots.

i) Ability to view multiple plots on one screen.

j) Archive reports and plots onto removable media, (i.e., floppy diskettes, zip drives, etc.).

k) Ability to generate custom reports by integrating data and plots using Clipboard (e.g., cut & paste function) or converting plot data or events list into standard DOS text format for use in a spreadsheet or word processing program.

l) Ability to save multiple alarm plots.

m) On-line rescaling and reconfiguration of points.

n) Maintain a list of the most current alarm events.

o) Ability to view startups and shutdowns with 1X/2X filtered data.

p) Ability to display machine train diagrams including user selectable positioning of current values with alarm status indication.

q) Store over 2 years of data for each point on the hard disk.

r) Save data to, or retrieve data from, a floppy disk.

s) Off-line test software to check for possible system communication faults, with a history file recording such faults.

t) Windows style on-line Help and Glossary that is context-sensitive and has flexible search capabilities, hypertext information and graphics. Must be printable by selected topics.

Revision Summary

30 July, 2003	Revised the "Next Planned Update". Reaffirmed the contents of the document, and reissued with minor revision.